IET Renewable Power Generation

Research Article

Analysis of operating reserve demand curves in power system operations in the presence of variable generation

ISSN 1752-1416
Received on 28th March 2016
Revised 18th January 2017
Accepted on 23rd January 2017
E-First on 30th May 2017
doi: 10.1049/iet-rpg.2016.0225
www.ietdl.org

Ibrahim Krad[1] ✉, David Wenzhong Gao[2], Erik Ela[3], Eduardo Ibanez[4], Hongyu Wu[5]
[1]*National Renewable Energy Laboratory, Golden, CO, USA*
[2]*Department of Electrical and Computer Engineering, University of Denver, Denver, CO, USA*
[3]*Electric Power Research Institute, Knoxville, TN, USA*
[4]*General Electric Energy Consulting, Schenectady, NY, USA*
[5]*Department of Electrical and Computer Engineering, Kansas State University, Manhattan, NY, USA*
✉ *E-mail: ibrahim.krad@nrel.gov*

Abstract: The electric power industry landscape is continually evolving. As emerging technologies such as wind and solar generating systems become more cost effective, traditional power system operating strategies will need to be re-evaluated. The presence of wind and solar generation (commonly referred to as variable generation or VG) can increase variability and uncertainty in the net-load profile. One mechanism to mitigate this issue is to schedule and dispatch additional operating reserves. These operating reserves aim to ensure that there is enough capacity online in the system to account for the increased variability and uncertainty occurring at finer temporal resolutions. A new operating reserve strategy, referred to as flexibility reserve, has been introduced in some regions. A similar implementation is explored in this study, and its implications on power system operations are analysed. Results show that flexibility reserve products can improve economic metrics, particularly in significantly reducing the number of scarcity pricing events, with minimal impacts on reliability metrics and production costs. The production costs increased due to increased VG curtailment – i.e. including the flexible ramping product in the commitment of excess thermal capacity that needed to remain online at the expense of VG output.

1 Introduction

As emerging technologies continue to become more significant players in the power system, operating strategies will need to evolve that allow system operators to mitigate adverse effects while maximising system benefits. Wind and solar generators, electric vehicles, and distributed generation located throughout the distribution system have recently drawn significant attention. These technologies may increase the variability and uncertainty in the power system if not properly controlled and operated. Power system operators may need new and improved methods to maintain the real-time balance between electricity generation and consumption. Traditionally, system operators have utilised a combination of operating reserves [1]. These requirements are typically based on simple heuristics developed independently by each footprint, without any consensus on a universal methodology to calculate how much reserves the system operator must acquire. Although contingency reserves are typically designed with $N-1$ reliability in mind, there is still much discussion about how operating reserves are procured.

New operating reserve methodologies are explored to address the additional variability and uncertainty from variable generation (VG) resources. Methodologies to determine operating reserves in recent wind integration studies and operating practice were examined in [2], where simulation results were compared with different methods or data. A statistical approach to assess the impact of intra-hour wind power variability on the quantity of primary reserve provided by wind generators was proposed in [3], where three reserve allocation strategies were compared in case studies. Market implications of dynamic reserve policies for managing uncertainty from renewable resources and contingencies were examined in [4], where different policies were compared and a locational reserve pricing scheme was proposed. Ela *et al.* [5] describes different assumptions and methods for calculating the amount of different types of reserves and how these methods have evolved over time. Ibanez *et al.* [6] describes the relationship between operating reserve and wind generation and compared three methodologies for calculating regulating and flexibility reserve in systems with wind generation. A dynamic operating reserve requirement that was updated on an hourly basis to account for the variability of wind power was presented in [7], where the requirement was driven by probabilistic forecast errors as well as the short-term variability of wind power generation. Their analysis showed that there are significant opportunities to modify a static reserve requirement, and this modification could potentially reduce the cost per MWh of wind power injected. Doherty and O'Malley [8] proposed a dynamic reserve requirement methodology based on the probability of load shedding. The requirement was determined by considering the reliability requirements of the system throughout the entire year with respect to the number of allowable load-shedding incidents per year. Their analysis showed that increasing wind power generation in the system increases the need for operating reserves and that reserve requirements that consider longer temporal horizons typically result in requirements larger than those for shorter temporal horizons. A dynamic economic dispatch problem was formulated to simultaneously schedule energy and reserves utilising an interior point algorithm in [9], where the model converged well with improved computational speed. Matos and Bessa [10] proposed an hourly, dynamic reserve requirement methodology based on risk indices, such as the loss of load probability. This formulation allows the system operators to examine the trade-off between acceptable risk levels and operating cost and decide on a reserve requirement that best suits the current operating needs of the system.

The industry is also interested in this new class of flexibility reserves. In [11], a framework was presented to determine the quantity of ramping reserves based on the standard deviation of ramping imbalance, i.e. the difference between scheduled and actual generation ramping rates. Navid and Rosenwald [12] developed a flexibility reserve methodology to address ramping concerns that can be integrated within the Midcontinent Independent System Operator's day-ahead market model. This method aims to prepare generation assets for variability and uncertainty in the net load. One of the potential benefits of this